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Managing cities with urban computing

Singapore Management University

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SMU Professors Lau Hoong Chuin and Lim Yun Fong are combining their mathematical, computational and business know-how to address challenges facing the inner-city deliveries of orders and shipments.

The interdisciplinary field of urban computing involves the acquisition and analysis of large amounts of data in order to tackle major issues faced by cities. One of these issues is the logistics of last-mile deliveries, a term used to describe the transportation of goods from hubs outside of the city to their final destinations in homes and businesses.

"With the rise of e-commerce and ageing populations in major cities like Singapore, last-mile deliveries exert tremendous pressures on the economic, environmental and social well-being of cities," says Professor Lau Hoong Chuin from the SMU School of Information Systems.

"Many trucks deliver goods or parcels to retailers, offices and households in urban areas every day," adds Professor Lim Yun Fong from the SMU Lee Kong Chian School of Business. Uncoordinated deliveries add to congestion, pollution and noise, he explains.

Professors Lau and Lim wanted to coordinate these last-mile deliveries so that fewer trucks would need to enter the urban area, substantially reducing traffic.

Professor Lau explains that the problem with the urban logistics industry in Singapore is that it is fragmented and unregulated, making it inefficient both operationally and environmentally. This is an issue in many large cities around the world. "I see the challenge and opportunity to create a positive impact by working on this problem," he says.

Together, the two professors worked on the project titled 'Market Mechanisms for Multi-Party Coordination of Urban Logistics Operations' to develop methods and technologies that would enable multiple parties in the last-mile supply chain to collaborate on a win-win basis.

DETERMINING THE WINNING BID

The professors first developed a system that allows multiple companies to consolidate their orders for delivery. They did this by employing the concept of Urban Consolidation Centres (UCCs). The UCCs receive goods carried by large trucks owned by multiple shipping companies and are responsible for delivering the goods within the city's centre. They either have their own fleet of vehicles to deliver the goods or a docking facility for goods to be transferred to other vehicles – vehicles belonging to other companies which are compliant with inner-city transportation laws. Cities such as Nijmegen in the Netherlands, Paris in France, and Fukuoka in Japan have operating UCCs that are located in the outskirts.

Professors Lau and Lim considered the case of a UCC that operates its own delivery vehicles. They designed an automated auction mechanism that allows shippers to specify their delivery requirements through a bidding process that allows shippers and the UCC to minimise their costs and, at the same time, maximise the UCC's total profit.

However, as this auction protocol did not consider companies' need to plan deliveries weeks ahead of time, Professors Lau and Lim refined the model to allow for a 'rolling horizon auction'. In this scenario, shippers can bid over successive

auctions up to four weeks in advance for spaces in carrier delivery vehicles. The capacity of the same truck is also up for bid in each auction. Announcements of the results of each bid throughout the four-week period are made to give losing bidders a chance to arrange for alternative means of delivery or to alter their bid prices and resubmit them in subsequent auctions. The auction mechanism still exists, but it is modified to consider a more complex set of factors.

The team's computational experiments showed that the rolling horizon model improves companies' revenues by 28% when compared to a single period auction. This method is able to generate more revenue as it reserves a truck's capacity for more profitable bids that may come along as the final auction week nears.

Taking the model a step further, the team developed a 'double auction' platform that allows shipping companies to indicate the amount they are willing to pay a carrier to deliver their goods from the UCC into the city. Likewise, delivery carriers indicate the amount they are willing to accept as a fee. Both types of companies will then specify the areas they need or are willing to deliver to, and an optimisation model will determine the winning bid based on all the information submitted. The team conducted a computational study using the model, and was successful in demonstrating the platform's effectiveness in saving costs for both shipping companies and delivery carriers.

PROGRAMMING INNER-CITY LOGISTICS

As an extension of this project, Professor Lau worked with a team of researchers from the National University of Singapore and Nanyang Technological University to consider a real-life case study of an urban zone in Singapore that includes five shopping malls. They identified a busy Singaporean precinct and conducted field studies in the area. Besides engaging with the stakeholders, such as the suppliers, carriers, shopping malls, retail shops and in-mall carriers, observations, questionnaires and semi-structured interviews were also carried out to map the situation in the region. After surveying the area, they found three main challenges: retail shops ordered their goods separately from one another; traffic density to and from the malls varied throughout the day and week; and the distribution of goods to and within malls was inefficient.

To encourage the stakeholders to collaborate in consolidating their orders and deliveries, the team developed the concept of Retail Precinct Management, which optimises the use of delivery routes and loading docks at malls, improving waiting and final delivery times.

The model integrates real-time and static data on moving traffic and shopping mall car parks to determine the best routes and time to load and unload delivery vehicles. The model is also capable of handling trucks that unload at a mall and thereafter deliver goods to other malls (either by hand or by using smaller vehicles, to save time at mall docking bays). From their calculations, using the model results in a 40% decrease in the usage of vehicles, and travel distance would be almost halved compared to usual distances travelled. Waiting times and carbon emissions would also be significantly reduced.

With the successful trial runs, the team plans to work with a large local logistics provider to test its platform, says Professor Lau.

Their main challenge during the project was engaging the stakeholders to participate in the initiative, says Professor Lau. It was hard for them to see that this research could, in the long term, lead to cost benefits for them. The team is now working on finding different ways to incentivise the stakeholders. They also plan to expand their studies to other retail clusters in Singapore and other countries, with hopes to play a role in relieving congestion in regional commercial hubs caused by a rapid flow of public, private and freight vehicles in and out of regional centres.

This project builds on years of professional collaboration and friendship between Professors Lau and Lim. "I know his research interests and capabilities well, so he was a natural choice!" says Professor Lau of their collaboration.

"Our backgrounds complement each other for this project. Professor Lau is an expert in using computers to solve complex, real-world problems and I am familiar with the theoretical methods for solving such problems," adds Professor Lim. ■